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TITLE- Summary Description of the AAP
Apollo Telescope Mount

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ABSTRACT

This memorandum describes the manned solar observatory designated the Apollo Telescope Mount (ATM) which is to be part of a new mission module, the LM/ATM in the Apollo Applications Program. The ATM contains an Experiment Package of solar observation instruments which will enable measurements to be made of the extreme ultraviolet and x-ray portions of the spectrum which do not penetrate the earth's atmosphere. Photographs in the white light spectral region will also be made of the corona and solar disc. A functional description of the various experiments, their supporting systems and subsystems is presented. The information presented herein reflects the ATM configuration as of February 1968.

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Case 620**DATE:** April 25, 1968**FROM:** L. A. Ferrara

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TECHNICAL MEMORANDUM**1.0 INTRODUCTION**

The Apollo Applications Program (AAP) has under development a manned solar observation system designated the Apollo Telescope Mount (ATM). The Apollo Telescope Mount is designed to be attached to the lower section of a modified Apollo Lunar Module (LM-A) in place of the LM descent stage, forming a new mission module designated the Lunar Module/Apollo Telescope Mount (LM/ATM). The ATM is being designed, developed and tested by the NASA Marshall Space Flight Center which is also responsible for the overall ATM project management. The NASA Manned Spacecraft Center has responsibility for the modified LM-A. The solar telescope experiments which mount in the ATM experiment package are being provided under separate subcontracts by the organization affiliated with the Principal Investigator for each experiment. This memorandum describes the functions of the ATM, its supporting subsystems and experiments. The description reflects the ATM systems design as of February 1968.

The LM/ATM is planned to be launched unmanned as the payload of an uprated Saturn 1B launch vehicle, and the flight is designated for mission planning purposes as AAP-4. The LM/ATM flight will be flown in conjunction with a manned CSM (flight AAP-3) as part of the AAP manned orbital workshop mission. The CSM will rendezvous and dock with the LM/ATM in earth orbit and extract the passive LM/ATM from the AAP-4 SLA. Two astronauts will transfer to the pressurized cabin in the LM-A in order to activate and checkout the spacecraft subsystems. After completion of checkout, the crew will return to the CSM; and the combined CSM-LM/ATM will then be boosted by the Service Module (SM) propulsion system from the initial rendezvous orbital altitude of 210 NM to approximately 230 NM; the boost will be time phased to intersect the orbital path of the quiescent unmanned Orbital Workshop/Airlock Module/Multiple Docking Adapter (OWS/AM/MDA). The terminal phase of the rendezvous maneuver as well as docking will be accomplished by the use of the LM-A and CSM reaction control systems (RCS). During the final portion of the terminal phase, the LM-A with two astronauts aboard will separate from the CSM which is under the control of one astronaut. The CSM will dock to the axial port (port 5) of the MDA and stabilize the OWS; the LM-A will then dock to port 4 of the MDA

using the LM RCS for maneuvering. To minimize difficulties (docking probe and drogue interchange, additional propellant consumption) associated with the originally planned double rendezvous, recent mission plans require the unmanned LM/ATM to make a remotely controlled rendezvous and dock to the MDA after the manned CSM has docked to the OWS/AM/MDA. Studies are underway to evaluate the program impact of the direct unmanned LM/ATM rendezvous and docking; however, no impact on ATM systems are foreseen in this operational mode.

2.0 ATM OBJECTIVES

The principal objectives of the LM/ATM mission are:

- a. to evaluate the ability of man to operate complex scientific instruments in the space environment.
- b. to acquire high resolution images and other data of the sun from above the earth's atmosphere during the period of energetic solar activity.

To accomplish the broad objective of obtaining precise scientific data on the solar disc and surrounding areas, the ATM is configured as a manned orbiting solar observatory with appropriate electro-optical equipment to observe and record the solar phenomena. The ATM is designed to permit the astronaut to select and guide the telescopes to specific target areas of interest, perform routine tasks on the experiment telescopes and film systems, such as operating adjustments, and change of camera film packs. In addition, the ATM will furnish the necessary subsystem support to the experiments in the form of environmental (thermal) control, electrical power, communications, pointing control, and means for mechanical support and protection. The design criteria for the hardware components comprising the LM/ATM is based on a six month orbital lifetime (Reference 2). In general, the design provides for redundant means (including manual) of performing all functions which effect crew safety and mission success.

3.0 ATM SYSTEMS

The Apollo Telescope Mount systems are divided into the following categories:

- a. Structural and Mechanical (including Thermal)
- b. Pointing and Control
- c. Electrical Power
- d. Instrumentation and Communications
- e. Experiments

3.1 Structural and Mechanical Subsystem

The ATM structural and mechanical subsystem includes the rack, experiment package, fine gimbal units, and thermal control.

3.1.1 Rack

The rack is an octagonal trusswork of tubular aluminum which will carry the ATM systems, support the LM-A and house the experiment package. During boost it is held in the Spacecraft Lunar Module Adapter (SLA) by the four LM attach points which distribute the LM/ATM loads to the launch vehicle and provide lateral stiffness to the SLA. The rack measures 232 inches across at the attach points and is 97.5 inches deep. Each rack end plane is a shear web beam, with a 112.8 inch diameter center hole to accommodate the experiment package support ring and outer gimbal support required for fine pointing of the experiment package. The lower section of the rack has been extended four feet to support a solar radiation shield, solar array deployment mechanisms, and components which must be thermally protected.

3.1.2 Experiment Package

The experiment package is an 82 inch diameter cylinder, 130 inches long which contains the telescopes and cameras for the solar observations. The optical devices are mounted on a thermally isolated cruciform spar which divides the package into four segments. The spar is surrounded by a cylindrical shroud which provides thermal and contamination protection. Figure 2 shows the outline of the rack and experiment package. It should be noted that the experiment package and rack extension protrude below the normal Instrument Unit (IU)/S-IVB interface and therefore requires a three foot structural spacer to be added between the SLA and the IU.

3.1.3 Fine Gimbal

The experiment package is attached to the rack via the support ring and a two flexure pivot gimbal system. These supports permit the experiment spar to be finely positioned +2° in pitch and yaw and +95° to -120° in the roll axis with respect to the ATM rack. Pyrotechnic actuated caging devices mechanically lock the experiment package to the rack to relieve the loads on the gimbal pivots during launch and docking. There are eight devices to constrain the experiment package in pitch and yaw, one device for roll.

3.1.4 Thermal Control

Film thermal sensitivity and critical optical alignment require close thermal control of the experiment package during experiment operation. The absolute lower temperature limit which the experiments optics can withstand without damage is -15°F . Such a condition may occur during the time preceding activation or during prolonged power-down orbital conditions. From a thermal standpoint, the preferred orbital storage mode is sun oriented, inertially stabilized with the active cooling system and heaters operational. Thermostatically controlled electric heaters are provided for each of the critical experiments. Table I lists the thermal requirements.

The ATM thermal control consists of both an active and a passive system. Rack mounted ATM components, such as batteries, electronics and control moment gyros are passively controlled through the application of proper thermal coatings and positioning with respect to heat sinks and radiating surfaces. The experiment package is thermally controlled by an active cooling system located on the canister; heat radiated by the spar mounted experiments is absorbed by cold plates on the inner surface of the shroud and transported by circulating coolant to radiators on the outside of the shroud, where heat is expelled to space.

Table I

EXPERIMENT THERMAL REQUIREMENTS*

Experiment	Heater Operating Temperature	Type Heater	Experiment Operating Temperature
(S082A) NRL/A	63°F	Stand-off	
(S082B) NRL/B	$\pm 1^{\circ}\text{F}$	Electric	
(S082) XUV Monitor			
(S052) HAO			
(S056) GSFC	70°F	Integral	
(S054) AS&E	$\pm 2^{\circ}\text{F}$	Electric	
(S083) HCO-C			
(S083) HCO/H- α ATM/H- α		Not required	70°F

*From Reference 5

To satisfy the diverse experiment thermal requirements, the interior of the experiment canister is actively cooled by sixteen coldplates (four coldplates are mounted on the inner canister surface in each experiment package quadrant). The circulating coolant will maintain the coldplate surfaces at $50^{\circ}\text{F} \pm 1^{\circ}\text{F}$, and the associated heaters (plus any internal heat generated in the experiment) will bring the individual experiment temperature up to the desired level. The power penalty for all experiment heaters is estimated at 331 watts, average. Radiators on the exposed sun-end sides of the cylindrical canister will reject the absorbed heat to space. Limited surface area (about 85 ft^2) is available for radiator mounting, and this requires a wide temperature range, high specific heat coolant such as methanol/water (80%/20%).

3.2 Pointing Control System

The ATM Pointing Control System (PCS) consists of coarse and fine pointing control subsystems. The coarse subsystem is the CMG control subsystem, and it will provide solar and orbital plane acquisition, automatic hold, and manual operation. It has the capacity of maintaining the inertial attitude of the configuration with the LM/ATM docked to the MDA. The fine or experiment pointing control subsystem, which is under control of the astronauts in the LM, is capable of target acquisition, offset pointing of the experiment package, and automatic hold. The fine pointing control subsystem acts as a vernier adjustment to the CMG control subsystem for positioning the experiment package. It also serves to isolate motion disturbances generated in the assembly from reaching the telescopes. Figure 3 is a functional block diagram of the ATM pointing and control system.

The PCS requirements are:

Pointing Accuracy	± 2.5 arcsec. (peak)-pitch and yaw ± 10 arcmin. (peak)-roll
Pointing Stability	± 2.5 arcsec. (RMS)-per 15 minute period (pitch and yaw)
Drift	± 7.5 arcmin. (RMS)-per 15 minute period (roll)
Jitter Rate*	± 1 arcsec. (RMS)-per second (pitch and yaw) ± 1 arcmin. (RMS)-per second (roll)

*Requirement under review

Position Offset

Reposition capability from any point to any other point within a 21 arc minute square nominally centered on the solar disc. Reposition and settling time shall not exceed one minute.

Roll Orientation

+95 to -120° degrees from zero roll reference.

Values given are considered design goals for component and system development. Accuracy as used herein refers to the ability of the pointing control system to precisely place the optical axis on a specified point on the solar disc in some reference coordinate system. The stability of the PCS refers to how well the system holds the initially acquired attitude in the presence of perturbing forces (such as thermal drift or crew motion) for the given time period. Jitter is defined as higher frequency attitude perturbations due to random phenomena which are superimposed on the perturbations affecting stability. The jitter limits are the minimum values necessary to prevent smearing of the photographic film of the experiment with the longest exposure time.

3.2.1 Control Moment Gyro Control Subsystem

The main element of the coarse pointing control subsystem is a group of three double-gimballed control moment gyros (CMG) mounted on the ATM rack trusswork to provide torques for coarse positioning of the ATM in roll, pitch and yaw. Torques are derived by controlling the rate of movement of the gyro gimbals of the constant speed inertia wheels, each of which has a spin angular momentum of at least 2000 foot-pound seconds. This momentum is of sufficient size to permit the CMG system to stabilize the entire configuration when the LM/ATM is docked to the MDA. The CMG's are not activated until the LM/ATM is docked to the MDA and the ATM solar panels are deployed.

The CMG control subsystem components are sensors, actuators, and computers that provide the following functions:

1. Sensors

- a. Six rate gyros (two each redundant gyros for roll, pitch and yaw axes) sense the rate of directional change and generate corresponding analog signals which are used in both the CMG Control Subsystem and the Experiment Pointing Control (EPC) Subsystem. The pitch and yaw rate gyros are mounted on the experiment spar, and provide rate information to damp EPC system motion during daylight operation, and an integrated

signal for spacecraft position and rate control in pitch and yaw during orbital darkside operation. The roll rate gyros are mounted on the ATM rack and provide position and rate information for roll control of both the vehicle and the experiment package.

- b. The acquisition sun sensor assembly is a coarse attitude reference device of photovoltaic cells which detects the Sun's center, and is used as the pitch and yaw reference for the ATM rack.
- c. A star tracker assembly is a double gimbal telescope that locks onto and tracks a star of known reference position. Comparision of the gimbal positions establish the roll reference for both the vehicle and the experiment package. CANOPUS is currently programmed as the primary reference star but because the deployed solar array panels may obstruct the view of CANOPUS for much of the mission time, the star ACHERNAR is planned to be programmed as a secondary reference.

2. Actuators

- a. The three identical control moment gyros previously described are the primary actuators which provide torques for ATM positioning. Each CMG is powered by an inverter assembly that converts 28 VDC to:
 - (1) 115 VAC, 3 Phase, 400 Hz power
(spin-up and running of the CMGs)
 - (2) 10 VAC, single phase, 800 Hz
(sensor and control reference)
 - (3) 10 VAC, single phase, 4.8 KHz
(sensor and control reference)
- b. Primary CMG momentum desaturation when the LM/ATM is docked to the OWS/AM/MDA will be by automatic gravity-gradient dump and the primary backup will be a manually controlled gravity-gradient dump. The secondary mode of momentum desaturation will be the CSM Reaction Control System. A Workshop Attitude Control System (WACS) mounted on the aft end of the S-IVB stage is being studied as an alternate momentum desaturation system.

3. Computers

- a. The ATM Control Computer is an analog device which contains the signal conditioning, mode control, and logic necessary to integrate the various PCS functions for both the CMG and the EPC control subsystems.
- b. The digital computer is used to augment the PCS control computer by computing required roll commands, experiment roll reference, instantaneous CMG momentum and attitude position for gravity-gradient momentum dump. It also provides timing signals for other ATM systems: auto mode switching, experiment shutter doors control, mission elapsed time for experiment data correlation.

3.2.2 Experiment Pointing Control (EPC) Subsystem

The EPC subsystem contains sensors and actuators to accomplish the fine pointing of the experiment package.

1. Sensors

- a. The rate gyros used for the EPC are common with the six gyros in the CMG control system, the outputs of which are used to position and control the fine pointing of the experiment spar.
- b. The fine sun sensor assembly provides the pitch and yaw attitude information necessary for fine pointing of the ATM experiment package and is rigidly mounted to the spar.

The fine sun sensor electronic assembly contains the required electronics to condition the detector output into usable attitude error signals and provides for offset pointing of the experiment package.

2. Actuators

- a. The EPC actuators are three DC motors which provide the necessary torque in roll, pitch and yaw to fine point the experiment package. The entire telescope system is positioned in roll by rotating the canister about the optical axis. The pitch and yaw actuators provide vernier adjustments to the inertial position previously established by the CMGs. Associated with the roll torque motor is the roll actuator switch which provides the astronaut with the means to position the experiment package in roll from his LM end EVA film retrieval work station.

- b. Attitude Control Assembly (Hand Controller) is an electromechanical device located on the ATM Control and Display panel in the LM-A. The astronaut uses the controller to position the Experiment Package and rack in all axes.

3.3 Electrical Power System (EPS)

The ATM electrical power is provided by a system of deployable solar cell arrays, charger-battery-regulator modules, power distribution units, monitoring and control units and the interconnecting cabling network. The power distribution network is shown in Figure 4. The EPS is sized to produce an average continuous power of 3.8 Kw at 28 (+2, -3) volts DC. Presently defined power requirements for operation of the ATM systems are 3.6 Kw (Avg) including 750 watts average power continuously available to the LM cabin. An external power transfer cable is being planned which will permit up to 2.5 Kw to be transferred from the ATM EPS to specific loads or up to 1.8 Kw from the AM EPS to specific LM/ATM loads. The ATM and AM power busses will not be paralleled under any circumstances.

3.3.1 Solar Arrays

When the LM/ATM docks to the OWS/AM/MDA four sets of folded panels will be deployed on "lazy-tong" booms from the sun-end of the ATM rack, in a cruciform configuration as shown in Figure 1. Two opposite wings of the array each contain 88 modules of photovoltaic cells, the other two wings contain 92 modules each. Every twenty solar cell modules (one panel) comprise a discrete electrical source which delivers energy, when illuminated, to an individual charger-battery-regulator module (CBRM), to simultaneously charge the battery and supply regulated power to the ATM systems. The modules are composed of 684, 2cm. x 2cm., .015 inch thick silicon cells bonded to a substrate and protected with .012 inch quartz cover glasses. The individual cells are series-parallel connected (114 series, 6 parallel) to produce the desired current and voltage characteristics; each module is rated at 35 watts DC., at 30°C.* The total solar array will have an active cell area of 1007 square feet, producing a nominal array power of 10.65 Kw at beginning of life and 55°C average light-time array temperature.

*Some modules will be procured with 228, 2cm x 6cm cells (2 cells in parallel, 114 in series). The electrical characteristics of the 2cm x 6cm cell modules will be equivalent to the 2cm x 2cm cell modules.

For low altitude earth orbital missions where a portion of each orbit is spent in darkness, the solar array must be sized to provide not only the operating load requirements but also battery recharge. In addition, the array power must be sized to accommodate distribution losses and charger-regulator inefficiencies. The power output of exposed photovoltaic cells degrade with time due to cover glass erosion and radiation damage. The ATM solar array design is based on a 0.5% radiation degradation per month for a six-month lifetime.

3.3.2 Charger-Battery-Regulator Module (CBRM)

The CBRM's receive the unregulated power from the solar cell panels at voltages which vary from 38 to 90 volts, depending on cell temperature. The CBRM will recharge the battery as well as provide the regulated DC voltage to the power buses during the lightside passage, transfer the load to the battery and regulate the battery voltage during the darkside passage. There are 18 CBRM's (one for each set of 20 solar cell modules) mounted on the ATM rack. The CBRM's draw power from separate sources, (solar panels or battery) but their outputs are combined through a power transfer distributor, and energize main and auxiliary distribution networks. Diode isolation permits these 18 power sources to contribute independently to the load, thus a loss of one branch reduces system capacity by 1/18.

- a. Battery - The battery for each module consists of 24 hermetically sealed, three electrode nickel-cadmium secondary (rechargeable) cells each of 20 ampere-hours rating. The third electrode on each cell provides a signal to the charger controller indicating the state of cell charge. The battery rated output voltage is 28.8 VDC at full charge and 26.4 VDC at 30% discharge.

The lifetime of nickel-cadmium cells is measured by the number of charge/discharge cycles the cell can be subjected to and still deliver specified current density at rated voltage. This lifetime varies as an inverse function of the depth of discharge of the cells. The ATM batteries are conservatively sized for an average discharge depth of 30% which should yield a 5800 cycle lifetime (Reference 7), or 12.5 months operation under the orbital parameters planned for the AAP-1 through AAP-4 missions. During emergency operation, the batteries could be discharged to a much greater depth for a few times with no adverse effects. (Reference 8)

b. Battery Charger - The charge controller of the CBRM receives power from the solar cell array and directs it to the battery at a given voltage and controlled current rate. The charger controller is basically a current regulator, with built in logic circuitry which senses battery voltage and current, and compares it with load voltage and current requirements. Energy is transferred from the solar array to the battery at a maximum rate, as long as the unregulated solar array bus voltage is higher than the required battery charging voltage, and the battery output voltage is lower than its full charge state. The "third" electrode in each battery cell signals the charger controller to decrease the charge current to minimum, when the charging cycle is nearing completion, thereby preventing an overcharge condition which could cause hydrogen formation, overheating of the sealed cells, and eventual battery case rupture through excessive pressure buildup.

c. Regulator - A pulse width modulated load regulator senses the output voltage about the nominal 28v DC value. When the regulated output bus voltage drops below the steady state level, due to a sudden power demand, the regulator switching logic increases the "on" time of the battery solar array input (which is at a higher voltage than the regulated bus), until the output voltage rises to the desired level.

If a higher than normal voltage is sensed at the output bus, the duration of the regulator switch closure is decreased, thereby reducing the average value of the output voltage to the specified value. The ATM regulator is a buck-boost type designed to hold the output bus voltage between 31 volts (full load) with an input that varies from 26.4v (battery minimum) to 90 volts (solar array maximum). An inductance in series with the regulator high speed switching transistor output releases energy into the load bus when the transistor is gated "off", thereby supplying a continuous current flow to the load and raising the average voltage as required to meet the limits (29-31 volts). Regulator efficiency is 85% at full load output of 450 watts.

3.3.3 ATM Electrical Power - Networks and Distribution Subsystem

The electrical power network will distribute, switch and protect the DC power for the ATM systems. It also provides access (through connectors mounted on the rack) for the carry-on and swing arm umbilicals of the Electrical Support Equipment during pre-launch checkout.

The Power Transfer Distributor accepts redundant inputs to the electrical power network from primary batteries, ESE umbilicals, and Charger-Battery-Regulator Modules, each separately fused and diode isolated. The redundant inputs from each source are split in the Power Transfer Distributor to provide two separately controlled and protected power buses, which are routed on redundant cables to the appropriate ATM systems via the main and auxiliary distribution networks. Each redundant load branch is protected by a fuse or circuit breaker, sized to protect the cabling from overheating. The fuses and circuit breakers are located in the various distribution boxes, and are not accessible in flight.

3.3.4 ATM Primary Batteries

A silver-zinc primary battery pack is mounted on the ATM Rack and connected to the ATM electrical power network through the Power Transfer Distributor. These batteries will be used to operate critical systems (mainly experiment package and CBRM heaters) in the ATM during the period from launch through deployment of the ATM solar panels. This primary source will consist of two, 350 Ampere-Hour, 20 cell units, of the type presently used in the IU. They will be capable of supplying an average power of 300 watts for seventy hours. Upon sun acquisition by the solar array, the primary battery system will be switched out of the circuit, and the main and auxiliary ATM load buses will be powered by the normal solar array/CBRM units. The secondary batteries in the CBRM can be manually switched to the load if the primary source is depleted, but they will have to be recharged before full load capability is available.

3.3.5 Control and Display (C & D) System

A control and display facility is located in the pressurized LM-A cabin to enable the astronauts to operate and monitor the performance of the various experiments and systems on the Apollo Telescope Mount. The controls and displays are grouped into a console arrangement, mounted in the left hand side of the LM-A access tunnel, as shown in Figure 9. The console will accommodate two astronaut operators, as mission activities require. The C & D console will provide monitoring indicators and control circuitry for the following ATM functions:

1. Electrical Power System monitoring and management.
2. Pointing Control System, including the manual controls for fine pointing of the Experiment Package.
3. Close circuit television monitors and camera controls. The six cameras associated with the experiments can be switched to either of the two TV monitors.
4. Individual experiment status and control panels.
5. Caution and Warning indicator panels.

Safety covers will be placed about the console switch area and indicators, to avoid inadvertent activation or damage by the astronauts moving about the cabin. The console provides more than eleven square feet of control surface area, requires 375 watts (peak) power to operate the displays, and will weigh no more than 500 pounds. AC power (about 100va) is required at the C & D console to operate the electroluminescent panels, PCS, & experiments. The AC power will be provided in the LM-A from the 750 watts average DC. power continuously supplied by the ATM, since there are no plans to supply general purpose AC from the ATM EPS. The PCS and TV monitors, because of their relatively high power consumption, will require active thermal control from the LM-A environmental control system to keep the panel surfaces at the desired average temperature of 71°F.

3.4 Instrumentation and Communication (I & C)

The ATM Instrumentation and Communication System is located on the rack structure and, except for the control and monitoring function, is independent of the LM-A. The system consists of measuring, telemetry, command, antenna, and closed circuit television subsystems as shown in Figures 5, 6, 7 and 8. The I & C system is comprised mainly of Saturn IB hardware. About 700 measurements reporting the status of the vehicle, experiments, and related ATM subsystem performance will be selectively recorded at a 4 kilobit/sec rate, and telemetered to a MSFN receiving station at a 72 kilobit/sec rate, whenever the LM/ATM is in view of a ground station. The command subsystem provides a means for ground checkout and remote operation of the ATM system. The closed circuit TV subsystem gives the astronaut at the C & D console in the LM-A cabin the means to monitor experiments and point the Experiment Package and Telescopes.

3.4.1 Measuring Subsystem

The measuring subsystem consists of transducers and accelerometers, mounted at selected measuring points, signal conditioners and measuring racks, which detect and prepare the analog signals for inputting to the telemetry subsystem.

Redundant Master Measuring Voltage Supplies provide precise reference voltages to the signal conditioning and measuring racks through the auxiliary power and measuring distributors.

There are eight signal conditioning racks, which passively condition up to 40 low level measurements in each rack. The high level measurement signals are actively conditioned in two measuring racks.

3.4.2 Telemetry Subsystem

The ATM telemetry subsystem contains equipment for the multiplexing of analog and digital data, encoding, formatting, and synchronizing of the data, tape storage and playback facilities, and VHF transmitters and antennas. Up to 300 low level (0-20 millivolts) DC inputs from the signal conditioner racks are accepted by a bank of five Remote Analog Submultiplexers (RASM). These inputs are sampled 12 times per second, interleaved into a serial bit stream, and amplified for transfer to the model 270 Multiplexers. A bank of four multiplexers take the inputs from the RASM's, the CMG measurements from the vibration analyzer, the Measuring Racks, and LM-A operational data. These data are combined with the digital data multiplexers to furnish two signal wavetrain outputs from the high level multiplexers. One output goes to the PCM/RF assembly, where the signals pulse code modulate an RF carrier, are then amplified to a ten watt power level, and applied to one of the telemetry antennas for real time transmission to the MSFN. The second output from the multiplexer is routed to the pulse code modulated digital data acquisition system (PCM/DDAS) assembly. The function of the ASAP unit is to extract the preselected data and record it on magnetic tape at a 4 KBPS rate for up to 90 minutes. Upon command (either locally from the C & D console or remotely via the Command uplink) the ASAP plays back the stored data at a rate 18 times faster than recorded, and modulates the ASAP/RF assembly for transmission to the MSFN at a 72 KBPS rate through the second telemetry antenna.

A coaxial switch permits each RF transmitter to be connected to either the telemetry antennas located on the ends of the solar cell wing panels, or the ground checkout equipment. The two transmitters are on different frequencies (231.9 and 235.0 mHz) to permit simultaneous transmission from each antenna,

thereby achieving the best coverage to the ground receiving station. Simultaneous transmission capability of real time and stored data is desirable, because the ASAP unit cannot record the 4 kilobit/sec bit stream at the same time it is "dumping" the stored data to the ground station, and therefore some data would be lost. Additionally, some data may be desired continuously in real time at the ground station or Mission Control Center for flight control analysis. A modulation switching unit permits the transmitters to be modulated individually (one by real time data, one from tape playback data) or simultaneously by either real time or taped data. To achieve best ground station coverage, simultaneous transmission of the dumped data (with the loss of some real time data) is the presently recommended operational mode. Continuing antenna design and coverage studies may indicate sufficient signal margin exists to allow simultaneous transmission of real time and taped data.

The measurements to be transmitted to the ground stations via the ATM telemetry link consist of analog, digital and events data concerned with ATM, LM-A, and experiments housekeeping functions as well as samples of the experiment data which are recorded on film. The currently identified measurements are listed below (Reference 8).

Experiments	184
ATM Subsystems monitoring (including experiment housekeeping)	476
LM-A operational data	60

The LM-A operational parameters which are required to be telemetered when the LM-A/ATM is docked to the OWS/AM/MDA are bridged to the ATM. After ATM activation, the LM-A communications system is shutdown, and LM/A data is simply downlinked on the ATM telemetry system.

Special monitoring of the LM/ATM payload status from launch to S-IVB burnout is provided. Two acoustic and 38 vibration measurements will be made at critical points on the LM/ATM and SLA structure during the boost phase. The data will be processed and telemetered to the ground stations via two wideband VHF transmitters and the existing Saturn 1B IU antenna system.

3.4.3 Command Subsystem

The ATM digital command subsystem consists of redundant type MCR-503D command receivers and decoders. The receiver is an updated version of the Saturn 1B IU command system. It detects the phase shift keyed command word which was transmitted from the ground station on a 450 mHz carrier, and outputs the composite baseband waveform to the decoder. The decoder demodulates and separates the 35 bit command word, performs an error check and routes the 18 information bits to the ATM switch selectors and/or control computer according to the command word internal address. For each command word received, after examination in the decoder for proper vehicle address and parity count, an Acceptance Verification Pulse is generated and transmitted back to the ground station via the ATM telemetry system to provide an automatic acknowledgment or Message Acceptance Pulse.

Through the use of five selector switches, up to 560 real time commands can be sent (one at a time) to the ATM, for remote control of the ATM subsystems and experiments. The switch selectors can also be controlled on board by inputs from the C & D console digital keyboard in the LM-A. The command decoder also inputs to the ATM digital and control computers, to provide automatic updating of information for the pointing control system, and systems timing section of the digital computer. The ATM command and timing functional relationship as shown in Figure 7.

3.4.4 Antenna Subsystem

The ATM antenna subsystem consists of two telemetry (TLM) transmitting antennas and two command receiving antennas. The antennas are mounted on panels located at the ends of two adjacent solar array wings as shown in Figure 1. Antenna coverage pattern studies are not completed due to lack of definition of the solar arrays, and shadowing effects of the orbital assembly. ATM system design goals require omnidirectional antennas with 90 percent ground network coverage for the command system and 75 percent coverage for telemetry. Present configurations show notched telemetry antennas and scimitar command antennas. This antenna configuration produces several objectionable nulls or blind spots in the antenna patterns, and present studies (Reference 10) indicate pairs of orthogonally mounted dipole antennas may produce more uniform and efficient coverage. Since these dipoles would be located on the end panels of the solar arrays in place of the present scimitar and notch antennas shown in Figure 1, difficulty may be experienced when the panels are in the stowed position.

The antennas are connected to their respective TLM transmitters, and command receivers on the ATM rack by flexible coaxial cable routed along the edge of the solar array wings. The location of the antennas on the ends of the solar array panels will not permit operation until the LM/ATM is activated and the solar panels have been deployed from the stowed position.

3.4.5 Television Subsystem

The ATM I & C television subsystem is shown in Figure 8. It is designed as a closed circuit system to permit the astronauts at the Control and Display Console to monitor the solar disc from any one of six cameras, and assist in pointing of the experiment package as required. The system consists of the six cameras mounted on the experiment spar, six camera control units to adjust optics and filters, redundant sync generators, and two video switches and monitors. The video switches and monitors permit either (or both) monitors to accept output of any camera. The TV cameras and their experiment assignments are listed in Table II.

3.5 Experiments

The ATM payload is the experiment package. Eight solar observation telescope systems with cameras, film cassettes, telemetry sensors, and six TV monitoring cameras are mounted on the experiment spar, which serves as a common optical bench. The experiments are loaded with camera and film at launch; each film load is calculated to last about 14 days under nominal frame exposure rates. Replacement sets of cameras and film for each experiment as required will be carried in the LM-A for subsequent exchange with the exposed film cassettes by an astronaut performing EVA.

Two of the experiments (NRL/A and NRL/B) are designed to be serviced in flight from the sun end of the experiment package, the remainder from access hatches in the side of the canister near the LM-ATM interface. A description of the experiments and their functions are listed in the subsequent paragraphs of this section.

3.5.1 White Light Coronagraph (S052) (Sponsored by High Altitude Observatory)

This instrument will photographically record high angular resolution images of the corona surrounding the sun in the region of 1.5 to 6.0 solar radii. The shape of the corona,

Table II
ATM TELEVISION CAMERA ASSIGNMENTS

Camera	Solar Experiment/Equipment Assigned	Function
I Low Light Level Vidicon (SEC tube)	HCO/Hydrogen-Alpha telescope (H α #1) ATM/Hydrogen-Alpha white light pointing telescope (H α #2) ATM experiment pointing subsystem sensor	Observe whole sun filtergrams in narrow band ($0.5 \pm 1 \text{ \AA}$) of the H- α region (6563 \AA). Vidicon field of view: Variable 7-35 arc minutes. Resolution: 1-6 arc seconds/TV line.
II Standard Vidicon	NRL/Extreme Ultraviolet (XUV) Monitor	Observe whole sun images in broad- band ($0.9-1.2 \text{ \AA}$) of the H- α region (6563 \AA) vidicon field of view 7-35 arc minutes variable with zoom capability. Although broader bandwidth, can serve as emergency backup for camera I. Assist astronaut to point to active area of sun.
III Low Light Level Vidicon (SEC tube with fibre optics)	NRL/White light monitoring telescope NRL/Long wavelength slit telescope	Observe solar images which have been converted from XUV portion of spectrum ($170 \text{ \AA}-550 \text{ \AA}$) to more sensitive part of spectrum. Field of View: 40 arc minutes.
IV Low Light Level Vidicon (SEC tube)	HCO/Long wavelength slit telescope	Observe sun in white light with narrow field of view. Designed as a pointing reference system to assist in fine pointing NRL/B expt. FOV; 3 arc minutes.
V Low Light Level Vidicon (SEC tube)	HAO/White light coronagraph (S052)	Solar images of H- α line to assist in alignment and pointing of UV spectro- meter telescope (S083).
VI Low Light Level Vidicon (SEC tube)		Experiment monitoring, verify contamin- ation presence, assist in experiment alignment.

its polarization, intensity, and correlation with features on the solar surface will be continuously observed during at least one complete solar rotation (approximately 28 days). A sealed camera and 35 mm film reel is mounted in a removable cassette and contains enough film for about 14 days of operation. The camera has four modes of operation under control of the astronaut operator at the C&D console in the LM-A. The normal or daily patrol mode will be used for routine photographing of the slowly occurring solar events. In addition there is a long patrol mode and two (slow and rapid) flare sequence modes.

Each camera/film cassette will weigh 19 lbs. with a volume of .27 ft³.

3.5.2 Extreme Ultraviolet (XUV) Spectrograph/Heliograph (S082 A/B) (Sponsored by Naval Research Laboratory)

XUV Spectroheliograph (S082 A)

The purpose of the XUV spectroheliograph is to photographically record radiation in selected wave lengths of the solar spectrum between 150 and 625 Angstroms while observing the solar surface and chromosphere. The instrument consists essentially of a concave grating which receives light directly from the sun and reflects a spectrum of solar images on the film. A 400 exposure film pack is provided which will normally be exposed once every 12 hours to record long time changes. A rapid sequence mode select switch is available at the C&D console to record quickly changing solar events as they occur. The film pack and camera have a volume of 2 ft³ and weigh 40 lbs.

XUV Spectrograph (S082 B)

A companion experiment, designated NLR/B, is the XUV Spectrograph which is designed to record line spectrograms of solar radiation in the spectral range 970 to 3940 Angstroms of small areas of the solar surface at various levels across the limb. This experiment has a camera/film cassette and mode of operation similar to (S082 A) except that it makes eight exposures for each of the 200 film strips instead of one exposure per strip as in (S082 A). It also utilizes the XUV monitor telescope described below, and incorporate a TV camera (Television Subsystem Camera IV) for a precise pointing reference for the experiment.

An XUV monitoring telescope is associated with this experiment. The monitoring telescope is separately housed and optically aligned with the XUV experiment. It will provide the astronaut at the C&D console monitor with a visual presentation of the solar image in extreme ultraviolet to identify solar phenomena which would not be visable at the longer wavelengths. To accomplish this, a special filter and converter translates the XUV to a shorter wavelength image which excites a video camera (TV camera No. III) in the closed circuit television subsystem.

3.5.3 X-Ray Spectrographic Telescope (S054)
(Sponsored by American Science and Engineering)

This experiment will photographically record x-ray emissions of solar flares with a resolution of 2 arc seconds. It will simultaneously record emissions in the 2 to 10 Angstrom spectrum with a resolution of less than one angstrom.

The instrument consists of a double-reflecting grazing incidence x-ray optical system with an objective grating which functions as a slitless spectrograph. A flare detector and an image dissector is mounted within the experiment in addition to the main telescope to provide an x-ray image of the sun to the astronaut at the C&D console. This display will enable the astronaut to observe flares on the solar surface and select active regions for closer examination. A sealed camera and 70 mm film cassette provides a nominal 14 days of operation. The cassette weighs 31 lbs. and measures 12" x 22" x 6" (.91 ft³).

The camera, under control of the astronaut at the C&D console can be operated in either a manual (astronaut initiated), automatic (picture sequences initiated every 5 minutes of sunlight), or rapid automatic (10 exposures/minute during flare development) mode.

3.5.4 Ultraviolet Scanning Spectrometer (S083)
(Sponsored by Harvard College Observatory)

UV Scanning Spectrometer

This instrument will observe and record selected spectral lines in the UV spectrum below 1300 Angstrom of selected small areas of the solar disc. It will also make radiation measurements of the photosphere, chromosphere and corona. The instrument consists of a spectrohelioscope which will examine

a 5 arc minute by 5 arc minute raster and transmit the scan line outputs from a bank of multi-channel photo-multipliers to the ATM telemetry system for transmission to MSFN.

Long Wavelength Spectrometer

The long wavelength (1300 \AA - 2200 \AA) spectrometer (HCO/B) has a hydrogen-alpha filter and narrow field of view vidicon associated with the clock and camera/film system to assist in alignment and pointing of the UV spectrometer. This H- α telescope and monitor system assists in pointing and alignment of the S083 scanning spectrometer (ATM Television Subsystem Camera V).

The film camera cassette associated with S083 weighs 15 lbs. and measures 14" x 11" x 5" (.5 ft³).

HCO/Hydrogen-Alpha Telescope (H α #1)

A separate HCO/H- α telescope system (H α #1) is provided to give a time annotated correlation of the photographic and telemetered data from S083 by photographing whole sun filtergrams in narrow band of the hydrogen-alpha line with a camera and vidicon monitoring system with a variable field of view (zoom capability), which can observe the entire solar disc or smaller areas of interest. This HCO/H- α telescope monitoring and mission elapsed time recording capability will also serve to correlate the other experiments which measure different wavelengths of solar radiation.

The camera/film cassettes for the HCO/H- α telescope are similar in size, weight, and function to the S083 experiment except that three spare cassettes are carried in the LM-A. Each cassette should record approximately 14 days of solar observations so that a complete H- α history of the ATM mission will be recovered.

3.5.5 X-Ray Telescope (S056) (Sponsored by GSFC)

This experiment utilizes a glancing incidence x-ray and extreme ultraviolet (XUV) telescope instrument with appropriate filters to observe the distribution of solar x-rays in a number of spectral bands in the wavelength region of 3 to 60 angstroms.

Solar images are recorded on 35 mm UV sensitive photographic film. One film/camera cassette is loaded in the instrument prior to launch and will last approximately 14 days. Each cassette weighs 13 lbs. and measures 15" x 11" x 3" (.3 ft³).

Total x-ray flux in the region of 2° Å to 8° Å will be measured by two proportional counters. The counters' outputs are recorded on magnetic tape for "dumping" to the MSFN via the ATM telemetry subsystem and further conditioned for C&D console activity indicators. A strip chart recorder in the LM-A will also be used to give a permanent time history of x-ray activity in the respective spectral regions.

4.0 APOLLO TELESCOPE MOUNT WEIGHT SUMMARY

The most recent estimates of the ATM component weights derived from References 6 and 9 are summarized in Table III.

5.0 APOLLO TELESCOPE MOUNT INTERFACES

The major interfaces of the ATM are structural, electrical power, control and display signal leads, and telemetry to the LM-A. In addition, the ATM rack will have a structural interface with the SLA through the LM attach points. A basic design criteria is to minimize all ATM interfaces, leading therefore to the many selfcontained subsystems as described in Section 3.0 of this report.

5.1 Structural Interface

The structural connections between the ATM rack and the LM-A are similar to the structural interface between the present Lunar Module ascent and descent stages except there will be no provision for emergency separation of the LM-A and the ATM rack.

5.2 Electrical Power

The ATM electrical power system will provide an average power of 750 watts continuously to the LM-A after solar array deployment. The interconnecting electrical cabling to the LM-A will be sized to handle peak electrical loads of 1600 W. An electrical ground cable will be run from a point ground on the ATM rack into the power terminal in the LM-A. These two sets of cables will penetrate the pressurized LM cabin via sealed feed-through connectors in the ascent engine well cover. An additional power transfer cable rated for one-hundred amperes will be run externally from the ATM electrical power bus, around the outside of the LM-A cabin to a riser which feeds through the LM-A docking tunnel. This set of cables will permit subsequent internal connection through the MDA to the electrical distribution panel in the Airlock Module for the transfer of up to 1800 watts to specific loads in the ATM. The cables can also be arranged to transfer power (up to 2500 watts) from the ATM power transfer distributor to specific loads in the AM. These two buses will not be paralleled.

Table III
APOLLO TELESCOPE MOUNT WEIGHT SUMMARY*

<u>Element</u>	<u>Weight (Pounds)</u>
Rack	13,210
• Structure	2851
• Instrumentation & Communication	706**
• Control System	1984
• Electrical Power System (18 CBRM)	2522
• Solar Arrays	4070
• Experiment Support Equipment	120
• Thermal Control System	180***
• Miscellaneous	777
<u>Experiment Package</u>	<u>5,218</u>
• Structure	2289
• Thermal Control System (Canister Liquid Cooling)	489****
• Experiments	2027
• Wiring	156
• Miscellaneous Brackets, etc.	257
PROJECTED ATM WEIGHT (3/1/68)	<u>18,428</u>
CONTROL WEIGHT ALLOCATED	<u>18,900</u>
GROWTH MARGIN	472 lbs.

* Source - References 6 and 9.

** Includes 20 lbs. for redundant command equipment.

*** Includes 150 lbs. estimate for additional passive thermal control.

****To be adjusted when active thermal design is firm.

The ATM electrical system will also interface with the launch pad Electrical Support Equipment (or ACE) through the SLA electrical umbilical connectors and drag-in cables when the LM/ATM is in the launch configuration. Existing SLA umbilical cables and connectors are undersized for the anticipated ATM pre-launch electrical loads. Drag-in cables will supply additional ground power to the ATM transfer distributor through the SLA access panels.

5.3 Controls and Displays

The ATM controls and displays will be mounted on consoles located in the left hand middle section of the LM-A access tunnel. Signal leads for these controls and displays will be routed through the ascent engine well cover to the appropriate experiments and instruments on the ATM.

5.4 Instrumentation and Communication

Provisions are made for 60 high level signals (primarily LM-A operational measurements) to be transferred to the ATM for multiplexing with the ATM telemetry data and subsequent transmission to the MSFN. A bridging network in the LM-A will supply these signals to the LM-A S-Band communications system and to the ATM VHF system. The data will be downlinked from whichever transmitter is enabled.

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Attachment
References
Figures 1-9

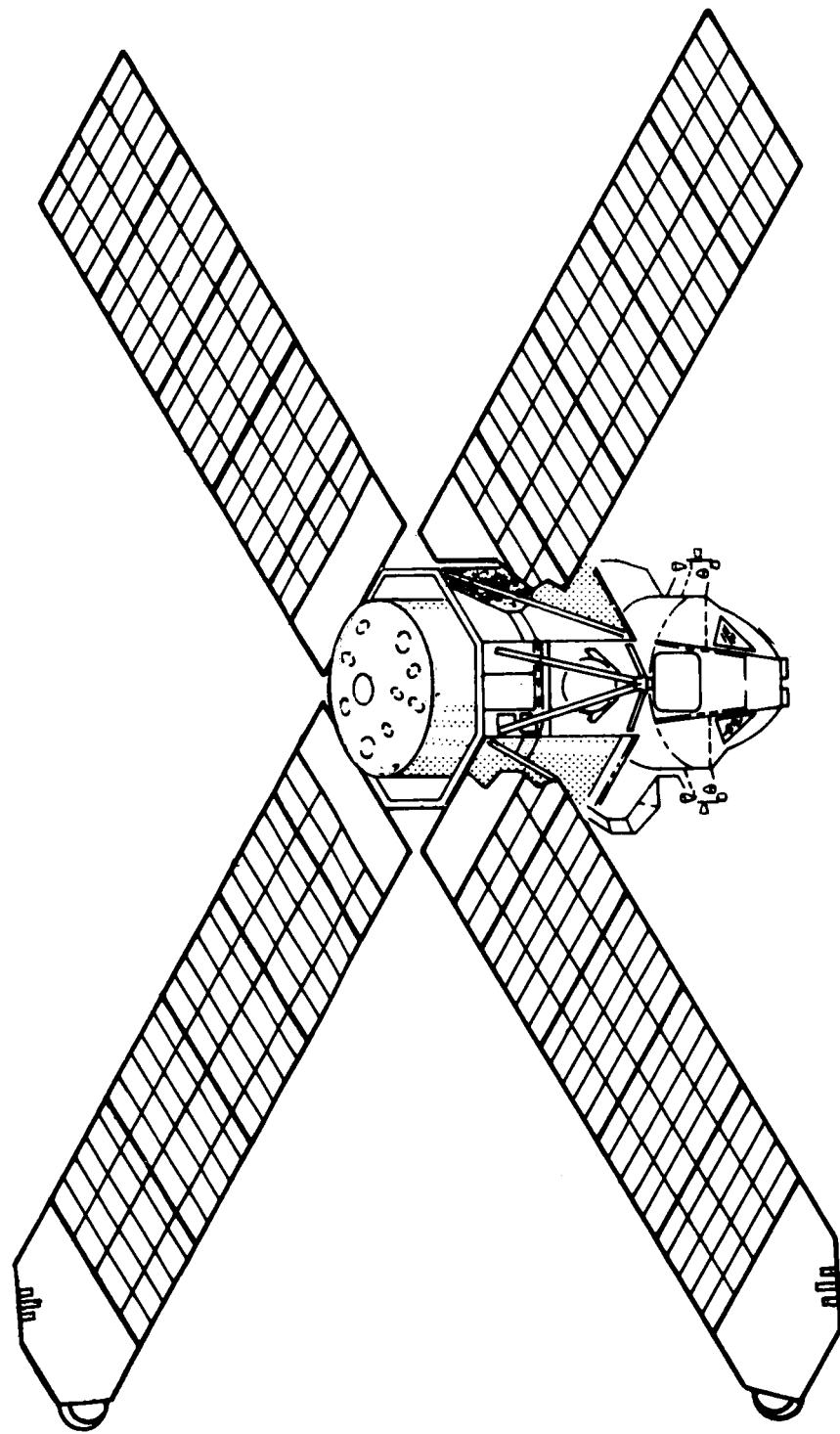


FIGURE 1 - LM / ATM

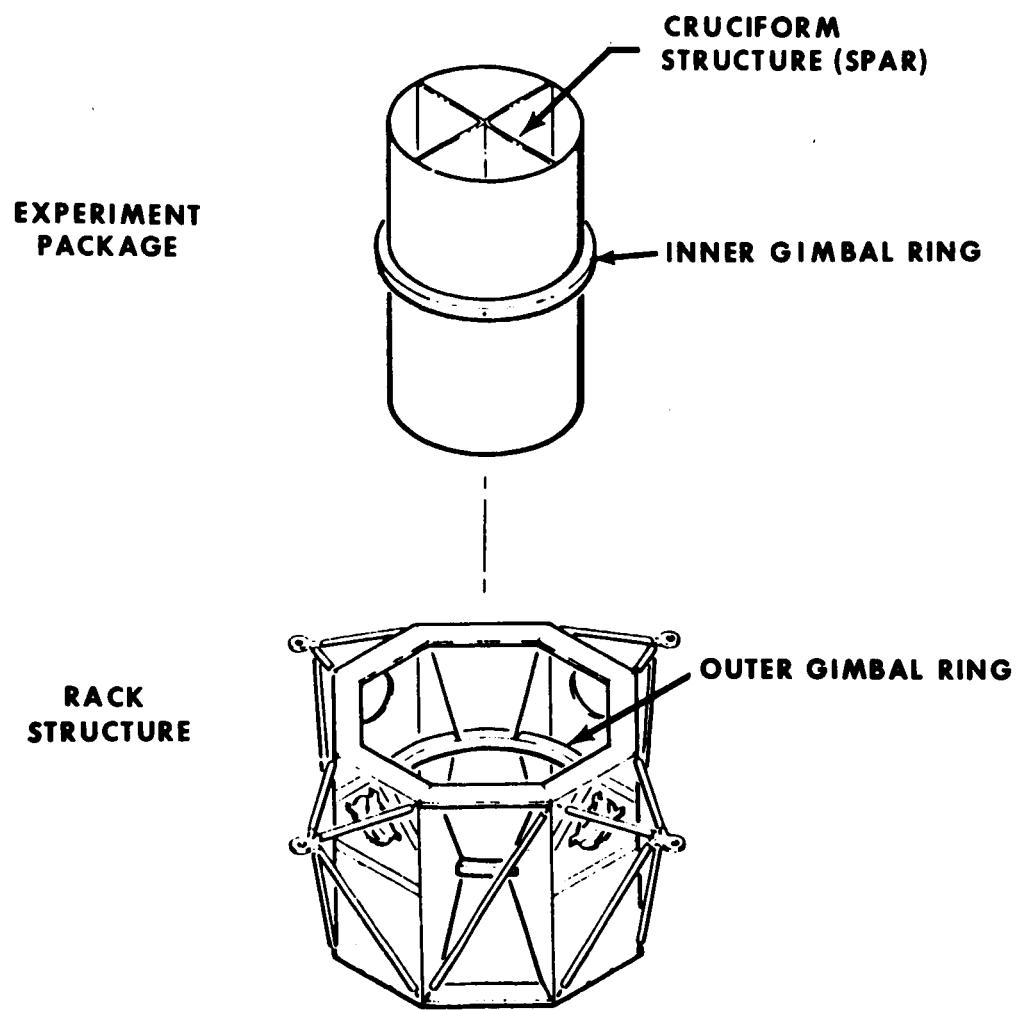


FIGURE 2 - ATM RACK AND EXPERIMENT PACKAGE

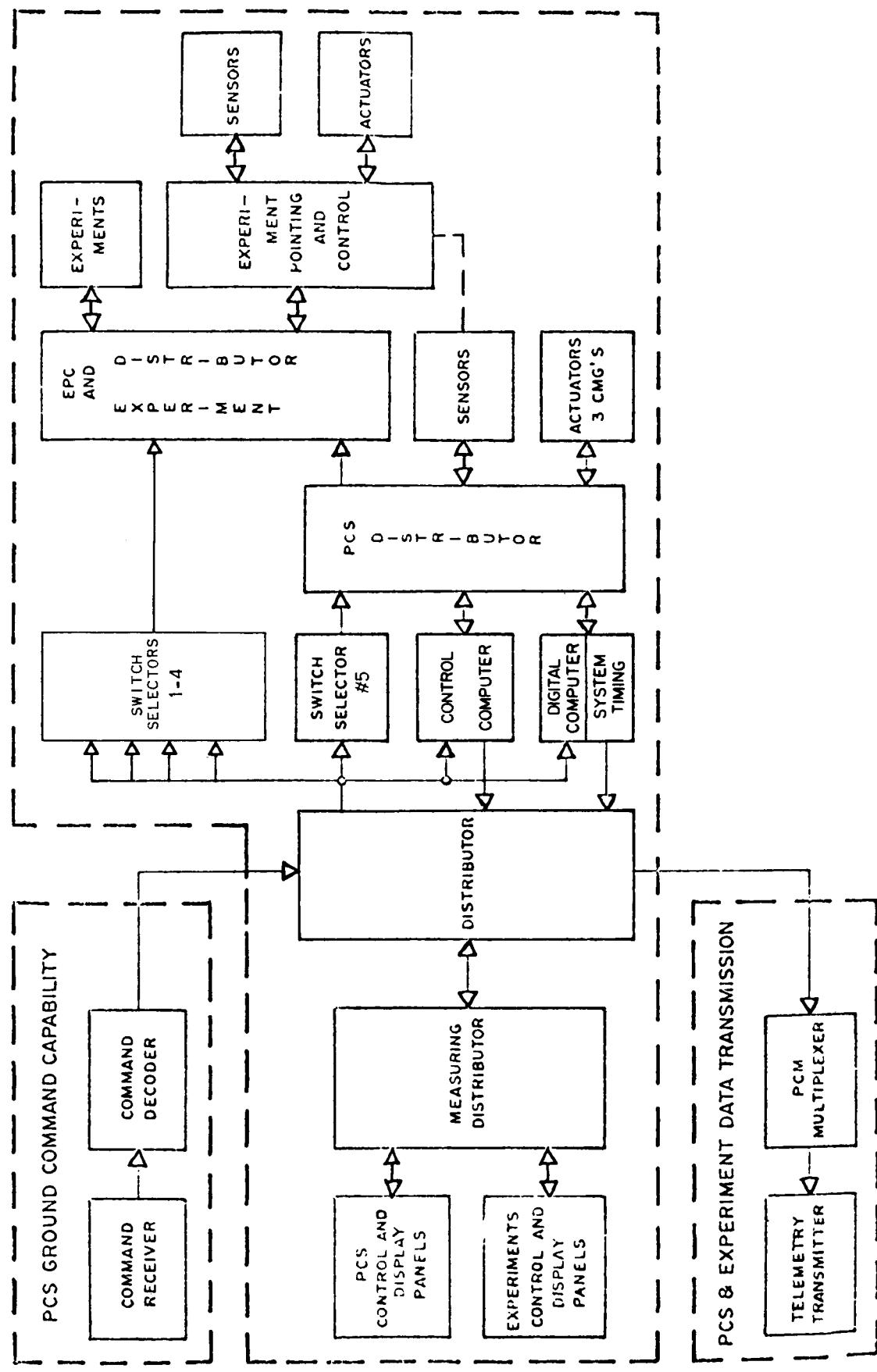


FIGURE 3 - POINTING AND CONTROL SYSTEM FUNCTIONAL BLOCK DIAGRAM

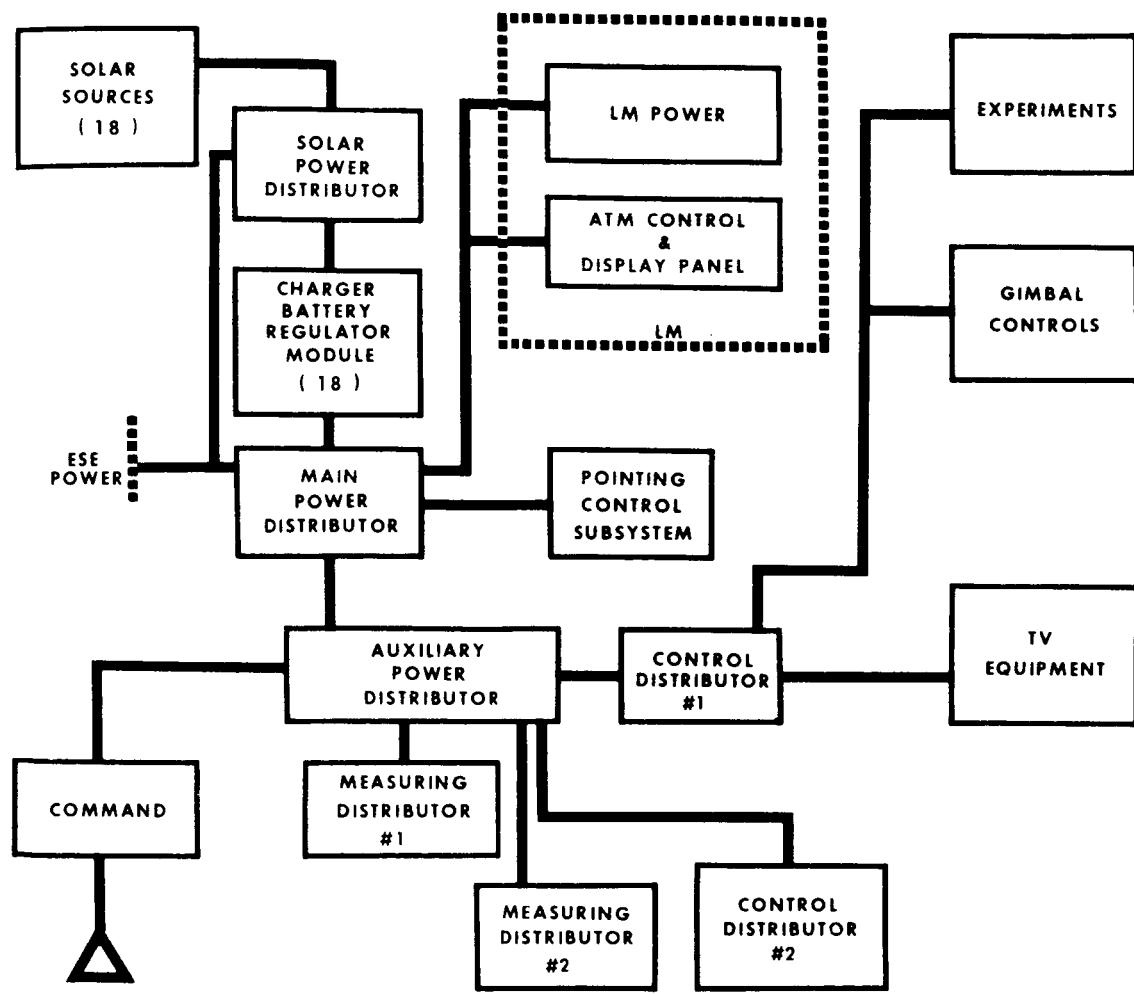


FIGURE 4 - ATM ELECTRICAL POWER DISTRIBUTION

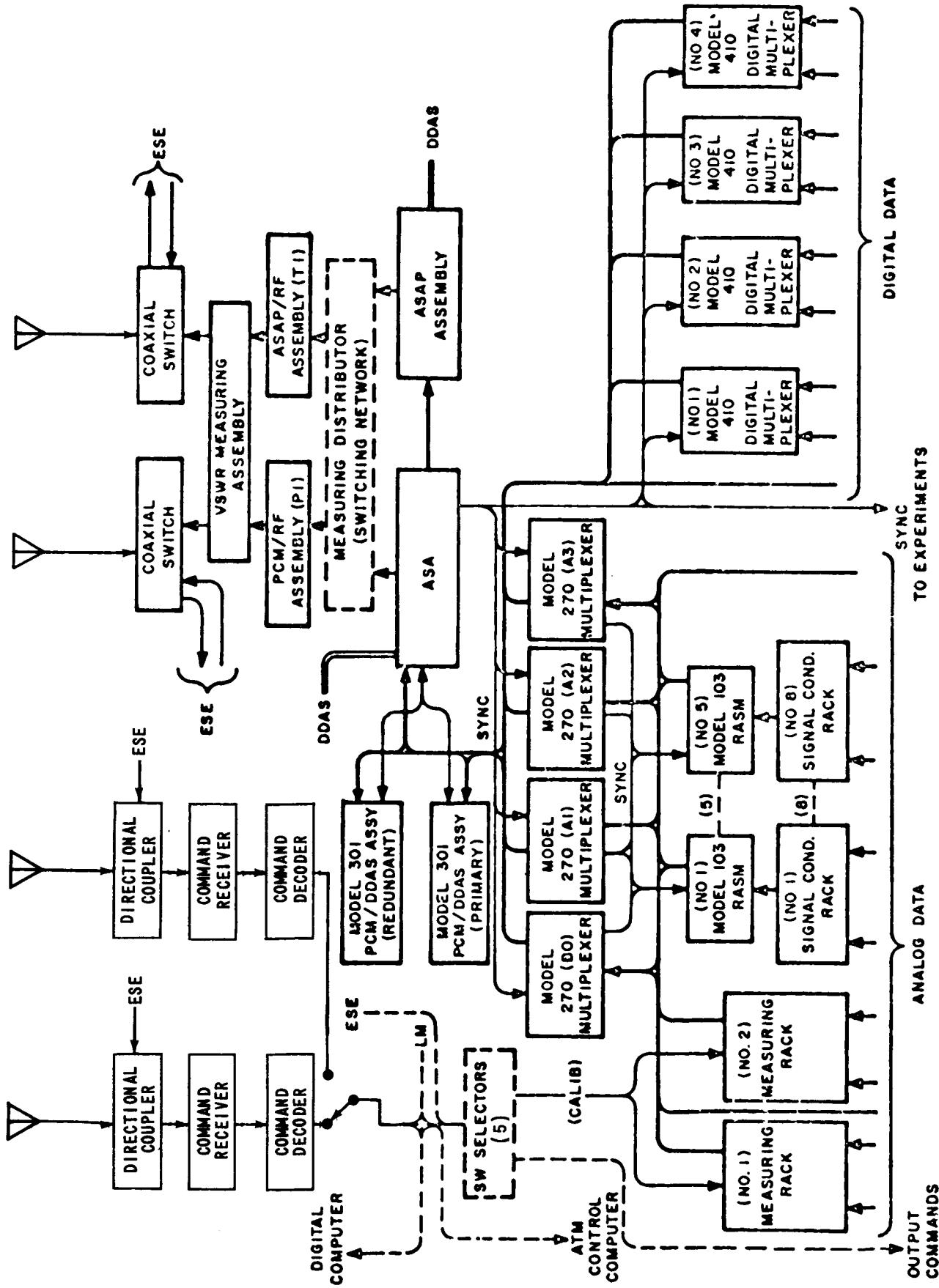


FIGURE 5 - INSTRUMENTATION AND COMMUNICATION SYSTEM BLOCK DIAGRAM

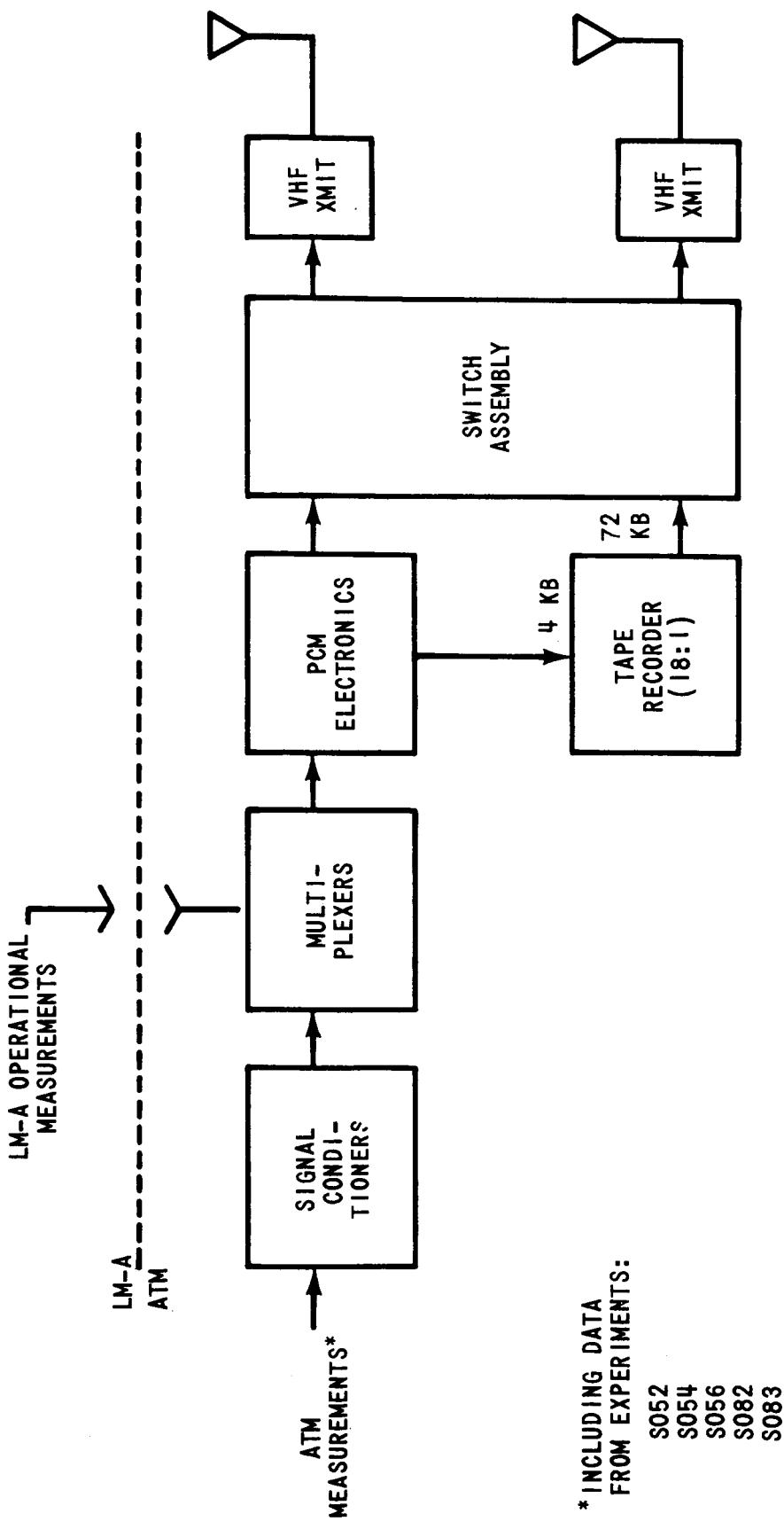


FIGURE 6 - ATM DATA SYSTEM

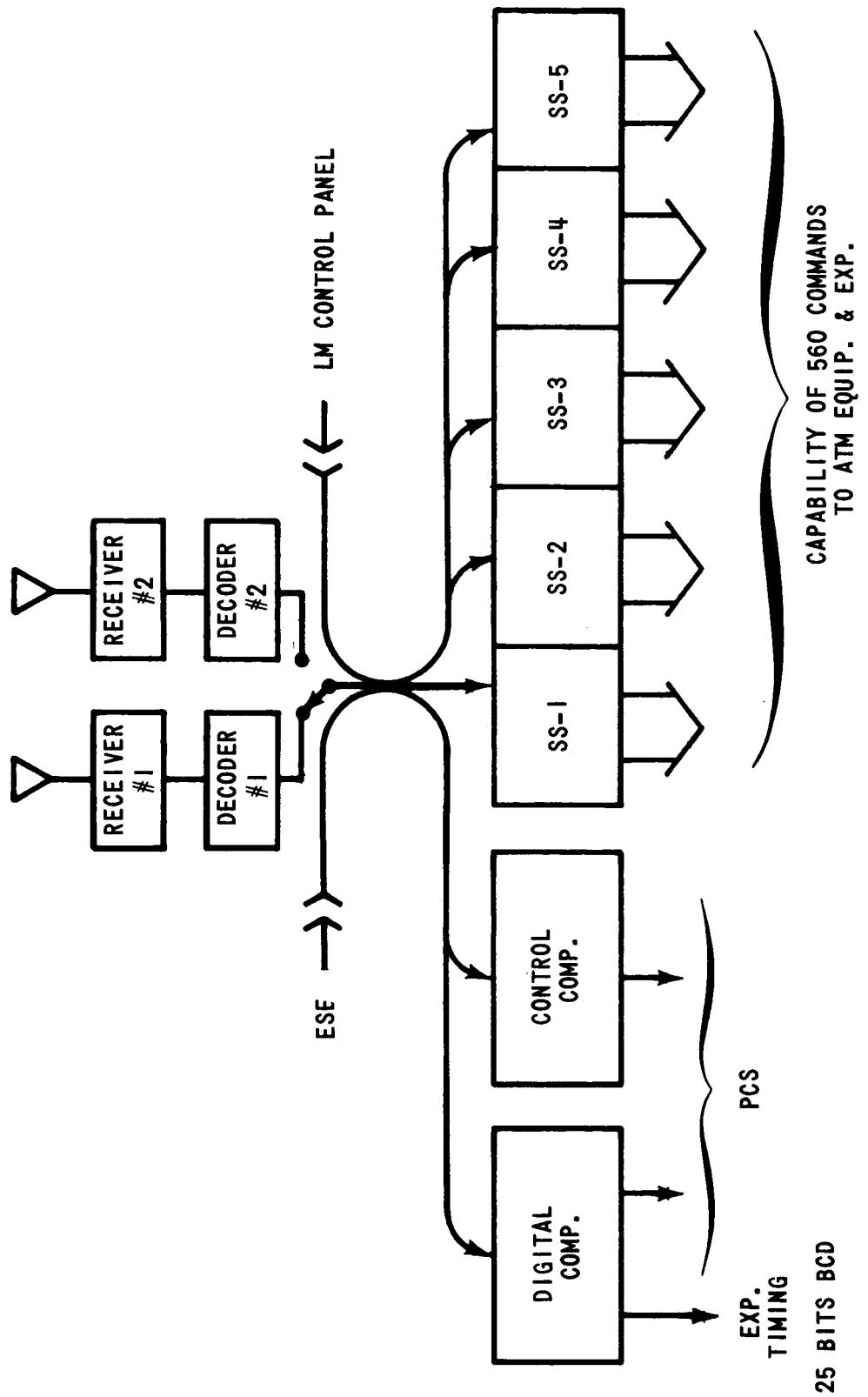


FIGURE 7 - ATM COMMAND AND TIMING SUBSYSTEMS

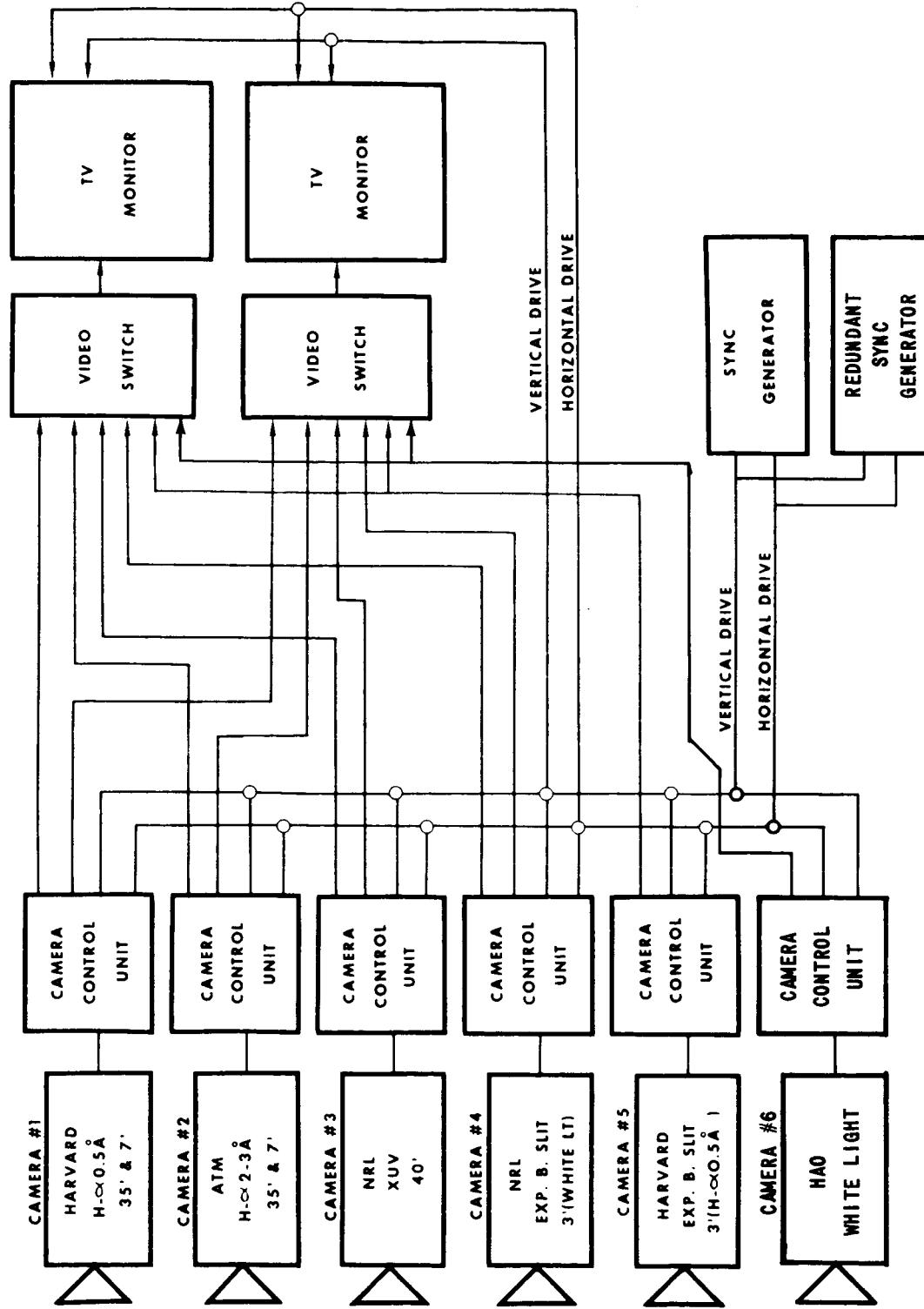


FIGURE 8 - TELEVISION BLOCK DIAGRAM

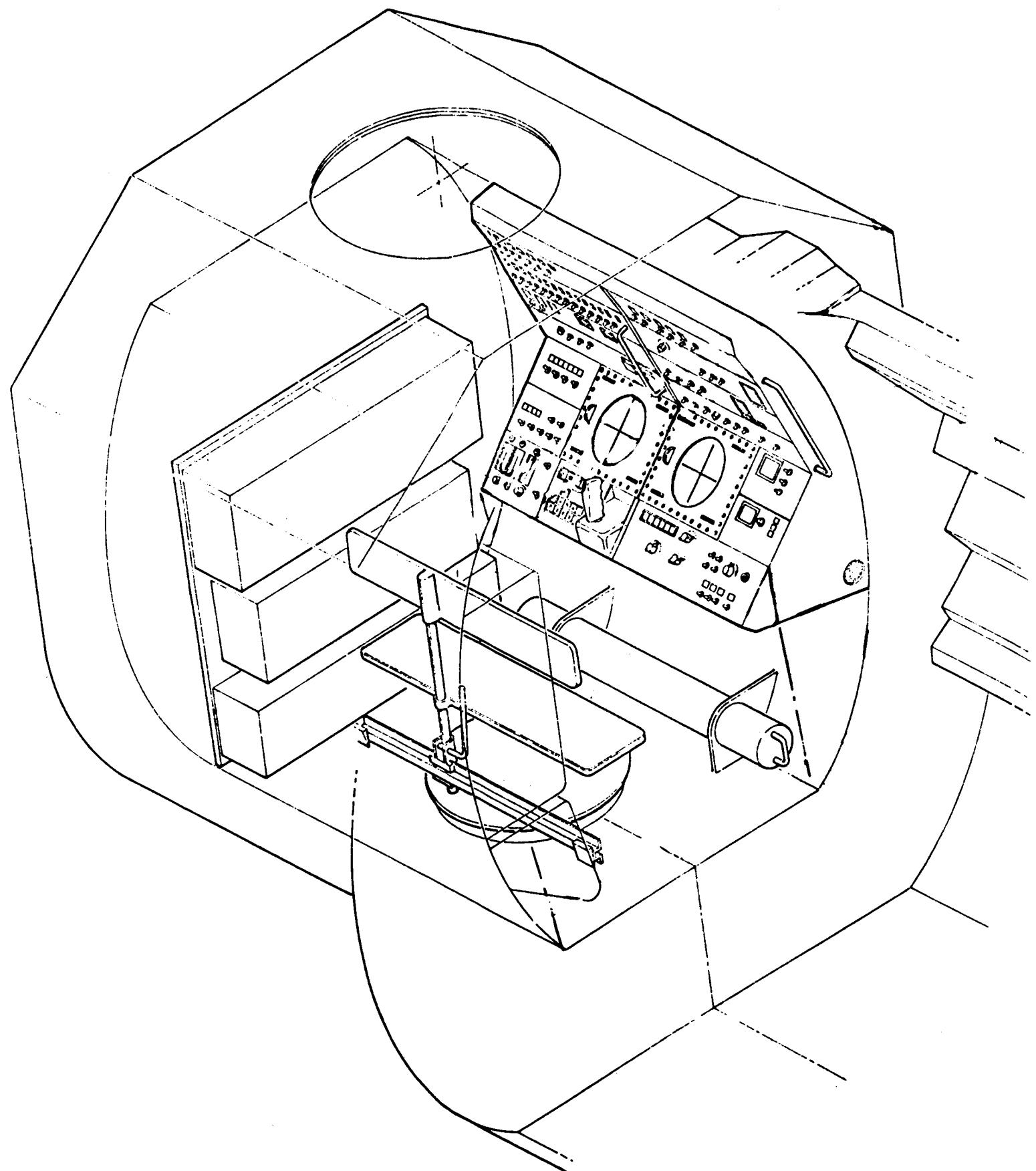


FIGURE 9 - ATM CONTROL AND DISPLAY CONSOLE

BELLCOMM, INC.

REFERENCES

1. ATM Technical Project Review, MSFC, September 6-7, 1967.
2. Baseline Review of AAP Missions 1 through 4, conducted October 12-13, 1967, NASA Headquarters.
3. Apollo Telescope Mount Project Development Plan, ATM Project Office, MSFC, April 13, 1967.
4. ATM Sun-End Film Retrieval, Augmentation Task No. 36, Lockheed Missiles and Space Company Report LMSC - A842327, September 5, 1967.
5. ATM Monthly Project Status Review - February 21, 1968.

6. AAP Weight and Performance Report, OMSF Apollo Applications Program, December 6, 1967.
7. Power Generation and Cryogenic Gas Storage System Study for Post AAP 1 through 4 Manned Missions, MSC Internal Note No. 67-EP-20, June 27, 1967.
8. ATM Electrical Power Subsystem Preliminary Requirements Review, MSFC, January 22, 1968.
9. Monthly AAP Weight and Performance Summary, February 15, 1968.
10. VHF Coverage Analysis, The Bendix Corporation, Navigation and Control Division-Denver Facility, Document BD-1140, February 29, 1968.